$ AF #19 8L 4-22-02
2113

GLAST, PHILLIPS & MURRAY

A PROFESSIONAL CORPORATION

John A. Thomas
(972) 419-8378
jathomas@gpm-law.com

Registered to practice before the U.S. Patent Office

2200 One Galleria Tower
13355 Noel Road, L.B. 48
Dallas, Texas 75240-1518
(972) 419-8300
Facsimile (972) 419-8329

Houston
(713) 237-3111

April 3, 2002

BOX: FEE
Assistant Commissioner for Patents
Washington, D.C. 20231

RE: Patent Application -- SINGLE CAMERA VIDEO INSPECTION SYSTEM FOR WATER WELLS AND BORE HOLES
Serial No. 09/259,000
Our File No. 09038.30

Dear Sir:

Enclosed for filing are the following:

1. Original and two copies of Applicant's Brief on Appeal and Appendix;

2. A check in the amount of $320.00; and

3. A self-addressed, stamped postcard which I would appreciate you date-stamping and returning to me upon receipt.

Thank you for your assistance in this matter.

Yours truly,

John A. Thomas

JAT/sdj
Enclosures
cc: Mr. Rick Toth (w/enclosure)

Certificate of Mailing Under 37 C.F.R. § 1.8
I, John A. Thomas, hereby certify that this correspondence for Serial No. 09/259,000 is being deposited with the United States Postal Service as first class mail, with sufficient postage, in an envelope addressed to: BOX; FEE, Assistant Commissioner for Patents, Washington, D.C. 20231, on the date indicated below:
Date: 4/3/02 Signature: John A. Thomas

Docket No. ______________________

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	§	**Group Art Unit: 2713**
	§	
GARY L. RUTLEDGE	§	
	§	**Examiner: Gims S. Philippe**
Serial No.: 09/259,000	§	
	§	
Filed: February 26, 1999	§	
	§	
For: SINGLE CAMERA VIDEO INSPECTION SYSTEM FOR WATER WELLS AND BORE HOLES	§ § § §	

APPLICANT'S

BRIEF ON APPEAL

John A. Thomas
Registration No. 29,980
GLAST, PHILLIPS & MURRAY, P.C.
13355 Noel Road, Suite 2200
Dallas, Texas 75240
(972) 419-8378
(972) 419-8329
jathomas@gpm-law.com

Table of Contents

BRIEF ON APPEAL

COPY OF PAPERS
ORIGINALLY FILED

Real Party in Interest

The real party in interest is Goulds Pumps, Inc., a Delaware corporation having an address of 4608 Bradley, Lubbock, Texas, as shown by assignments recorded at Reel 012173, Frame 0084, and at Reel 9799, Frame 0124.

Status of Claims

Claims 1-9, 18, 19, 23-33 are the subject of this appeal. No other claims are pending. Claims 10-17 and 20-22 have been canceled.

Status of Amendments

No amendments have been filed after final rejection.

Summary of Invention

The invention is directed to a system for video inspection of boreholes, pipes, wells, and the like. The application discloses two embodiments of the invention. Both embodiments use image sensors, such as charge-coupled devices (CCD's), which are connected to one or more camera control boards. Such boards generally have processors for processing the data from a CCD and producing a conventional video signal.

Fig. 6 shows a single camera (30) including two image sensors (32) coupled to a single camera board and processor (34). A single camera (30) may have multiple image

sensors (32) but only one camera board and processor (34). Suitable optics (38) focus the image on the image sensor (32).

Fig. 7 shows a double-camera embodiment of the invention. Here, a camera assembly (24) has an upper housing (40). The upper housing (40) includes two camera boards and processors (also called "control boards" in the application) (42 and 44). The control boards (42 and 44) are operatively connected to two cameras (52 and 54).

A lower housing (41) has side view camera (52) that views a plane perpendicular to the long axis of the bore hole or pipe, and a down view camera (54) views a direction approximately 90 degrees from that of the side view camera (52). The latter direction is down the long axis of the bore hole or pipe. The lower housing (41) is mounted so that the side view camera (52) can be rotated while the down view camera (54) stays fixed. Preferably, side view camera (52) is rotated by means of a stepper motor (48).

Another embodiment of the invention uses a single camera with a single image sensor to view the side of the bore hole, down the long axis of the bore hole, and any angle in between. This embodiment is depicted in Figs. 8 and 9. In Fig. 8A, the camera assembly (24) consists of an upper section (56a) and a lower section (56b). The upper section (56a) includes a camera control board (34).

As shown in Figs. 8B and 8C, the lower section (56b) of the camera assembly (24) has two parts; an upper part (66) coupled to a lower part (68) by a pair of pivot arms (74, 76). The pivot arms (74, 76) are rigidly mounted to the upper part (66) and the lower part (68) by pivot shafts. This connection allows the lower part (68) to be suspended and able to rotate 90 degrees from a down-hole view to a side-hole view. Lower part (68)

includes the camera enclosure which contains a single image sensor (70), as well as lights (72).

The lower section (56b) has a high-torque dc motor (78) connected to a chain and sprocket system (80) within one of the pivot arms (76). The dc motor (78) can thus rotate the lower part (68) 90 degrees to change the view of the image sensor (70) from down-hole to side-hole.

The upper part (66) of the lower section (56b) is coupled to the upper section (56a) by a hollow shaft (64) that can be rotated by a stepper motor (62) located in the upper section (56a). Thus the image sensor (70) may be rotated by the combined movement of the two motors (62, 78) to capture views from any point 360 degrees around the bore hole and from perpendicular to the side of the bore hole to the down-hole view. Figure 9 shows a close-up view of the lower section (56b) of the camera system (60).

Figure 10 shows an embodiment of the invention with multiple image sensors; that is; one or more side-view sensors (84), and a down-view sensor (82) coupled to a single camera board (34), forming a single camera with multiple image sensors. As described above in the first embodiment, the side-view sensors (84) can be rotated so that the side-view sensors (84) can capture a complete 360-degree image around the inside of the bore hole or pipe.

In all of the embodiments just described, the camera board (34) is connected to a conventional interface control (61) that prepares a video signal for transmission through a coaxial cable (18) to a place where the image can be viewed. Fig. 1 shows a complete system, comprising the camera assembly (24), coaxial cable (18), cable arm (20), cable spool (16), and carrying case (1). The carrying case (1) includes the control system (9)

for the apparatus and a monitor (5) for viewing the received images. Figs. 2-6 show these elements in more detail.

Issues

Issue 1

Whether claims 1-4, 9, 18, 19, and 23-25 are patentable under 35 U.S.C. § 103 over *Federau* (U.S. Patent 4,532,544).

Issue 2

Whether claims 5-8 and 26-33 are patentable under 35 U.S.C. § 103 over *Federau* in view of *Barbour* (U.S. Patent 5,652,617), and further in view of *Berman, et al* (U.S. Patent 5,528, 453).

Grouping of Claims

For each ground of rejection which appellant contests that applies to more than one claim, such additional claims, to the extent separately identified and argued below, do not stand or fall together.

Argument

To establish a prima facie case of obviousness on the references cited, the Examiner must show:

(a) prior art references that teach or suggest all the claim limitations;

(b) some suggestion or motivation to modify the reference or combine reference teachings;

(c) the prior art must suggest the desirability of the claimed invention; and,

(d) there must be a reasonable expectation of success.

See, generally, MPEP § 2143.

Issue 1

Whether claims 1-4, 9, 18, 19, and 23-25 are patentable under 35 U.S.C. § 103 over *Federau* (U.S. Patent 4,532,544).

All limitations test not met

Applicant will show that the references cited by the Examiner, when combined, do not teach or suggest all of Applicant's claim limitations. The Examiner fails to cite references containing, in combination, all elements of claims 1-4, 9, 18, 19, and 23-25. Therefore, no prima facie case of obviousness has been made. MPEP § 2143.03.

The only reference relied on by the Examiner to reject this group of claims is *Federau.* Applicant requested the Examiner to reduce evidence within his personal knowledge as to what would be obvious to one skilled in the art to an affidavit, as required by 37 C.F.R. Section 1.107(b). The Examiner has not done so.

The meaning of the claim elements is determined by reference to the specification. 37 C.F.R. § 1.75(d)(1). "The specification is always highly relevant to the claim construction analysis. Usually, it is dispositive; it is the single best guide to the meaning of a disputed term." *Vitronics Corp. v. Conceptronic, Inc.*, 39 USPQ 2d 1573, 1577 (Fed. Cir. 1996); citing *Markman v. Westview Instruments, Inc.*, 34 USPQ 2d 1321, 1330 (Fed. Cir. 1995) (en banc), aff'd, 38 USPQ 2d 1039 (1996).

No "image sensor" in Federau

Federau does not disclose an "image sensor" as claimed. The *Federau* "sensor" is a line scanning device. *Federau* builds up a panoramic image of a bore by rotating a

scanning line around the bore. As shown in Fig. 1 of *Federau*, and in col. 4, lines 26-32, the object space imaged by the *Federau* system is a "...narrow line-shaped area oriented parallel to the optical axis 19." The "line sensor" of *Federau* is a line of "sensor elements 27." Col. 5, lines 1-10. These sensor elements are simply photosensitive detectors, not cameras capable of capturing an entire image. Each single sensor element defines a scan line on the object space as it is rotated around the panoramic axis (i.e., the long axis of the hole or pipe). Col. 4, lines 2-10. *Federau* constructs an image from these sensor elements by reading data from the line sequentially, and transfers the data to an "operating circuit 17, which in turn generates video signals and transmits them to a subsequent image processor." Col. 4, lines 14-25.

The "sensor elements" of Applicant's claim 1, on the other hand, are cameras, which capture an entire image of the bore hole wall in one video frame. See, e.g., application, page 11, lines 28-30: "Lower part 68 comprises the camera enclosure which contains a single image sensor 70 with a wide-angle lens. Image sensor 70 typically includes a CCD-type image sensor." (The application, at p.13, lines 18-25, discusses a multiple sensor (camera) embodiment capable of capturing two views at planes ninety degrees apart.) It is well known in the art that CCD's are "charge-coupled" arrays of photosensitive devices which are employed in television cameras. Such devices capture an entire television image frame. See, Christiansen, Donald, ed., *Electronics Engineers' Handbook*, 4th Ed., McGraw-Hill, 1997, Ch. 24.2. (Appendix, p. 7, et seq.)

Thus *Federau* does not disclose the image sensor which is claimed by Applicant, and the "all limitations" test is not met.

No first and second image sensors in Federau

As stated in the argument above, the multiple "sensor elements" disclosed by *Federau* are not equivalent to the two camera sensors claimed by Applicant. *Federau*'s sensing elements are embodied into one line-imaging system, which constructs one panoramic image of the inside of a bore hole, one image slice at a time. See, col. 4, lines 26-33; col. 3, lines 16-22. Thus, *Federau* does not contain the first and second image sensors required by claim 1, and again the "all limitations" test is not met.

No first and second directions in Federau

Claim 1 also has the limitation that the first image sensor acquires an image in a first direction along an axis, and the second image sensor acquires an image in a second direction, essentially perpendicular to the first direction. Contrary to the Examiner's opinion on page 2 of the office action of June 5, 2000, *Federau* discloses no such arrangement. *Federau* discloses one and only one direction to acquire an image of the object space; that is, the inside of the hole being inspected, and this direction is perpendicular to the axis of movement down the hole. See, e.g., Fig. 1 of *Federau*. In the cited office action, the Examiner refers to the sensor elements 27 of *Federau's* Fig. 2 (the line of sensor elements) and another "sensor" 47 in Fig. 1. This second sensor 47 is a "stationary synchro-sensor" mounted on the rotatable camera head 41. This sensor reads an encoding disc 45 as a way to synchronize the generated video signals with the radial position of the camera body. Col. 4, lines 58-68 This second sensor 47 is in no sense a camera and does not acquire any image of the hole to be inspected. Thus, *Federau* does not contain the first and second directions required by claim 1, and again the "all limitations" test is not met.

<u>*Federau's image sensor is not equivalent to Applicant's image sensor*</u>

Even if *Federau* is considered to properly disclose the image-sensor element of Applicant's claims, the "sensor elements" and the imaging system built from them by *Federau* are not the equivalents of the camera system disclosed by applicant. First, any such equivalency must be recognized in the prior art, and cannot be based on an applicant's disclosure or the mere fact that the components at issue are functional or mechanical equivalents. MPEP § 2144.06, citing *In re Ruff*, 118 USPQ 340 (CCPA 1958). Second, any claimed equivalency must be determined under the "function, way, result" test. If the prior art reference (on an element-by-element basis) performs substantially the same function in substantially the same way to achieve substantially the same result, the reference will be considered the equivalent of the claimed invention. *Hilton-Davis Chemical Co. v. Warner-Jenkinson Co.*, 35 USPQ2d 1641, 1645 (Fed. Cir. 1995), *rev'd and remanded on other grounds*, 41 USPQ2d 1865 (1997).

Clearly, *Federau's* image sensors do not perform the same function in the same way. The "image capture" function in *Federau* operates by building up axial scan lines of an object space by rotating a line of individual photosensitive sensors. The "image capture" function in Applicant's claims operates by capturing an entire television frame on a charge-coupled camera. Applicant's camera is rotated axially to capture additional frames for inspection, not to build up a frame of scan lines in the first place. The Federal Circuit has addressed this precise point, and has held that such elements are not equivalents. *Digital Biometrics, Inc. v. Identix, Inc.*, 47 USPQ 2d 1418 (Fed. Cir. 1998). In the *Identix* case, the Federal Circuit held that data generated by a charge-coupled device was not equivalent to data input into image arrays. The Digital Biometrics' device

generated "arrays of slice data characteristic of adjacent and overlapping two-dimensional slices of the fingerprint image." The Identix device took analog data generated by a CCD fingerprint image, and analyzed that data. "The data that the CCD generates represents a complete image...". *Identix*, at 1428. Since the "sensing elements" of *Federau* are not equivalent to the "sensors" of Applicant, and thus not present in Applicant's claims, the prima facie case of obviousness has not been made.

Further, the modification of the *Federau* reference proposed by the Examiner on page 3 of the office action of January 16, 2001, would change the principle of operation of the reference. The *Federau* apparatus would have to be changed from a line scanning system to a frame-capturing system. Thus the teachings of *Federau* cannot render claim 1 prima-facie obvious. MPEP, § 2143.01, citing *In re Ratti*, 123 USPQ 349 (CCPA 1959).

No teaching or suggestion to modify Federau

The *Federau* reference contains no teaching or suggestion to combine the "sensor elements" into an array such as in a typical CCD camera imager and place this array in a television camera, as does Applicant. Indeed, *Federau* teaches away from this suggestion. See, e.g., *Federau*, col. 1, lines 50-68, and col. 2, lines 1-6. *Federau* cites the "characteristic features" of his "on-line" camera as, among others, that "...each sensor element defines a scanning line with rotational symmetry to the panoramic axis." Further, that such a camera "...makes it possible to create on-line TV images with large field angles in a very simple manner, and with simple and exact geometric relations between object and image." *Federau* points out "important advantages" over TV cameras having raster scans with an "energetic beam," and scanning over the object space

of the image plane of a "conventional TV-camera." Col. 2., lines 21-39. This scanning over an object space is exactly what happens in a CCD device, as charge packets are transferred out of the device.

Federau also points out the possible image distortions and complex geometric relationships between image and object that can result from such "conventional" TV cameras. Col. 2, lines 31-39. The CCD imaging array in a TV camera such as that chosen by Applicant is a raster-scanning device. See, e.g. Christiansen, cited above, at paragraphs 24.2.5-24.2.8, discussing methods for transferring the television frame from a CCD. Thus *Federau* not only fails to suggest using TV cameras with CCD sensor arrays as the imaging device for his application, but fails to even mention the scanning of a television frame from such devices. Thus there is no teaching or suggestion to combine *Federau*'s "sensing elements" in his line sensor into a fully functioning TV camera as implemented by Applicant in his claims.

No suggestion of desirability of claimed invention

To make a prima facie case of obviousness, the prior art must suggest the desirability of making the claimed invention. No such suggestion is present in *Federau.* In fact, as discussed in the previous paragraphs, *Federau* suggests just the opposite; that the use of other than his scanning system has serious disadvantages. On this ground also, the prima facie case fails.

Claim 18 in view of Federau

Applicant' arguments above regarding the citation of *Federau* as rendering claim 1 obvious are equally relevant to the Examiner's rejection of independent claim 18. The meaning of "sensor" in Applicant's disclosure and *Federau* are not equivalent, as shown

above. Thus not all elements in claim 18 are present in the one reference cited and no prima facie case of obviousness is made.

Further, Applicant points out that Applicant's sensor (a TV camera) is disclosed to rotate perpendicular to the direction of travel of the housing. As disclosed in Figs. 8a, 8b, and 8c of the application, the image sensor 70 in lower housing 68 rotates approximately ninety degrees to the upper housing 60. In contrast, in *Federau*, the entire imaging system rotates so that the inside of the bore is scanned by a one-line array of sensing elements. See, discussion of *Federau* above. Thus, there is no identity of elements and the prima facie case of obviousness is not made.

<u>*Dependent claims*</u>

Claims 2-4, and 9 are dependent on claim 1, and therefore allowable. Claims 19, and 23-25 are dependent on claim 18, and therefore allowable. Claim 2 is, however, independently allowable. Claim 2 adds the limitation that the second image sensor is an array of image sensors operable to acquire an image 360 degrees around the first axis (i.e., the down-hole axis) without rotating the second image sensor. The Examiner, in on page 3 of the office action of January 16, 2001, says this arrangement is equivalent to the "area sensor not moved or rotated with respect to the optical system" in *Federau.* A glance at Fig. 1 of *Federau* will show this assertion is completely mistaken. The line sensor 23 of *Federau* is not moved with respect to its optical system because the sensor and the optical system are both fixedly mounted in a tube 43 mounted on the camera head 41. The entire camera head, including the optical system and the line sensor 23, then rotate to build up the scan lines of an image, as described above. Col. 4, lines 40-57. In the application, page 9, lines 1-14, Applicant describes a single camera 30 including

multiple image sensors 32. The sensors are CCD's which acquire a complete image frame. The different frames thus acquired may be viewed by switching between image sensors. Clearly, sufficient image sensors could be provided to acquire a collection of frames that together would cover 360 degrees of view. For the reasons stated above, *Federau* does not disclose this element. Even if it did, the respective elements are not equivalents, for the reasons set out above.

Issue 2

Whether claims 5-8 and 26-33 are patentable under 35 U.S.C. § 103 over *Federau* in view of *Barbour* (U.S. Patent 5,652,617), and further in view of *Berman, et al* (U.S. Patent 5,528, 453).

Claim 5 is dependent on claim 3, which is dependent on claim 1. Claim 1 has been shown to be allowable for the reasons stated above, and thus claim 5 is allowable, regardless of the *Barbour* and *Berman, et al.* references. Claims 6-8 depend on claim 5 and are allowable. Claims 26-28 are dependent on claim 25, itself dependent on claim 18. Claim 18 has been shown to be allowable for the reasons stated above, and thus claims 26-28 are allowable.

The Examiner has rejected independent claim 29 under 35 U.S.C. § 103(a) as obvious over *Federau* in view of *Barbour* and further in view of *Berman, et al.* However, claim 29 contains the element of a camera assembly, which assembly has:

> a single camera operable to capture an image in a first direction, and,
> capture an image in a second direction ninety degrees offset from the first direction.

Claim 29 contains a limitation not found in *Federau*, *Barbour*, or *Berman, et al.*, this being <u>a single camera</u> operable to capture an image in a first and second directions. *Barbour* discloses two cameras; *Berman, et al.* disclose a single video camera only to

illustrate that it may be carried by the cart which is the subject of the patent; it is not disclosed as operable to acquire images in holes, or to do so in any particular way. The prima facie case of obviousness of claim 29 cannot be made, since an element of claim 29 is not found in any of the references cited. Claims 30-32 are dependent on claim 29 and thus allowable.

Claim 33 contains all the limitations of claim 18. For the reasons stated above, claim 18 is allowable over *Federau*. In the office action of October 10, 2001, at page 4, the Examiner rejects Applicant's argument that claims5-8, and 26-33 do not contain the limitation of a single camera operable to capture and image in a first and second directions. The Examiner asserts *Federau* teaches controlling the line sensor individually in order to avoid error caused by different illumination, and that this "is analogous to the claimed single camera since the line sensor contain [sic] a camera." Both of these assertions are mistaken.

First, *Federau* teaches controlling each sensor <u>element</u> 27 in his line sensor 23, not the sensor line as a whole. The sensor elements 27 are simply photosensitive regions, not cameras capable of acquiring an image frame. Even the line sensor 23 they compose does not do this; it scans the object surface and the image is composed from these scans elsewhere. Col. 5, lines 1-5; Figs 1 and 2. Second, since the line sensor clearly does not "contain" a camera, nor is it analogous to a camera, the limitation of a single camera or image sensor is not met.

Even if *Federau* did disclose the single-camera limitation of claim 33, the combination of *Federau*, *Barbour*, and *Berman, et al.* does not disclose other elements of claim 33. For example, no combination of the references teaches or suggests the lower

section coupled to the upper section; the lower section operable to rotate; the lower section further comprising an upper part and a lower part; the lower part having an image sensor and operable to pivot from a side view to a down view and any position in between. Applicant's claim 33, lines 5-15.

Conclusion

For the reasons stated, Applicant respectfully contends that each claim is patentable and solicits the reversal of all rejections.

Respectfully Submitted,

GLAST, PHILLIPS & MURRAY, P.C.

By John A. Thomas

John A. Thomas
Registration No. 29,980

13355 Noel Road, Suite 2200
Dallas, Texas 75240
(972) 419-8378
(972) 419-8329
jathomas@gpm-law.com

CERTIFICATE OF MAILING

I hereby certify that this correspondence will be deposited with the United States Postal Service by First Class Mail, postage prepaid, in an envelope addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231, on the date below.

Date: 4/13/02

John A. Thomas

John A. Thomas

Appendix

1. A video inspection system comprising:

a first image sensor having a plurality of sensor elements, the first image sensor operable to acquire an image in a first direction along a first axis;

a second image sensor having a plurality of sensor elements, the second image sensor operable to acquire an image in a second direction essentially perpendicular to the first direction; and

a camera board and processor coupled to the first image sensor and the second image sensor, the camera board and processor operable to receive an image from either the first image sensor or the second image sensor and prepare the image for display.

2. The video inspection system of Claim 1, wherein the second image sensor is an array of image sensors operable to acquire an image 360 degrees around the first axis without rotating the second image sensor.

3. The video inspection system of Claim 1, wherein the first image sensor, the second image sensor, and the camera board and processor are mounted in a water tight, pressure sealed camera assembly for use in a bore hole or water well.

4. The video inspection system of Claim 1, wherein the first image sensor, the second image sensor, and the camera board and processor are mounted in a sealed

camera assembly for use in a pipeline and the first axis is parallel to the long axis of the pipeline.

5. The video inspection system of Claim 3, wherein the camera assembly transmits images to a monitor via coaxial cable, the monitor operable to receive the output of the camera board and processor.

6. The video inspection system of Claim 5, wherein the coaxial cable includes a quick disconnect to allow easy removal and installation of other camera assemblies or tools.

7. The video inspection system of Claim 5, wherein the coaxial cable is stored on a spool in a transportable case.

8. The video inspection system of Claim 5, wherein the coaxial cable passes over a cable arm encoder operable to determine the distance that the camera has traveled and display it on the monitor with the output of the camera board and processor.

9. The video inspection system of Claim 1, wherein the first image sensor, the second image sensor, and the camera board and processor are mounted in a camera assembly operable to rotate about the first axis when the second image sensor is acquiring an image.

18. A video inspection system comprising:

a housing rotatable from a first direction along the long axis of an object being inspected to a second direction approximately perpendicular to the first direction;

an image sensor coupled to the housing, the image sensor operable to capture an image in the first direction, the image sensor further operable to capture an image in the second direction due to a rotation of the housing; and

a camera board and processor coupled to the image sensor and operable to process each image and prepare it for display.

19. The video inspection system of Claim 18, wherein the housing is operable to rotate around the first axis, the image sensor operable to capture an image when in a first position, a second position and any position in between thereby providing hemispherical coverage at a given location of the object being inspected.

23. The video inspection system of Claim 18, wherein the image sensor is mounted in a water tight, pressure sealed camera assembly for use in a bore hole or water well.

24. The video inspection system of Claim 18, wherein the image sensor is mounted in a sealed camera assembly for use in a pipeline.

25. The video inspection system of Claim 18, wherein the image sensor is mounted in a sealed camera assembly and the camera assembly is attached to a monitor

via coaxial cable, the monitor operable to receive the output of the camera board and processor.

26. The video inspection system of Claim 25, wherein the coaxial cable includes a quick disconnect to allow easy removal and installation of other camera assemblies or tools.

27. The video inspection system of Claim 25, wherein the coaxial cable is stored on a spool in a transportable case.

28. The video inspection system of Claim 25, wherein the coaxial cable passes over a cable arm encoder operable to determine the distance that the camera has traveled and display it on the monitor with the output of the camera board and processor.

29. A system for video inspection of a passage comprising:

a carrying case having a deep housing and a removable cover;

a spool adapted for storing coaxial cable inside the carrying case, the coaxial cable exiting the carrying case at an opening;

a cable arm supported by an adjustable leg, the cable arm attached to the carrying case, the cable arm operable to have the coaxial cable pass over it; and

a camera assembly, coupled to the coaxial cable, having a single camera operable to capture an image in a first direction along a long axis of the object being

inspected and capture an image in a second direction, the second direction ninety degrees offset from the first direction.

30. The system of Claim 29, wherein the carrying case further includes a monitor operable to display the image captured by the single camera.

31. The system of Claim 29, wherein the coaxial cable includes a quick disconnect near the camera assembly.

32. The system of Claim 29, further including a cable arm encoder operable to measure the length of cable to determine the distance the camera assembly has traveled.

33. A video inspection system comprising:

a camera assembly including:

an upper section having a camera card;

a stepper motor coupled to the end of the upper section; and

a lower section coupled to the upper section and the stepper motor, the lower section operable to rotate about an axis when the stepper motor is operational, the lower section further comprising:

an upper part having a high torque dc motor; and

a lower part coupled to the upper part by a pivoting means, the pivoting means driven by the high torque motor and operable to pivot the lower part from a down view to a side view, the lower part further comprising an image sensor coupled to the camera card and operable to acquire an image in a down position and a side position and any position in between, the image sensor further operable to acquire an image as the lower section rotates about an axis.

ELECTRONICS ENGINEERS' HANDBOOK

Donald Christiansen Editor in Chief

President and principal, Informatica; Fellow, the Institute of Electrical and Electronics Engineers; Fellow, World Academy of Art and Science; Eminent Member, Eta Kappa Nu; Editor Emeritus, IEEE Spectrum; *former Staff Director, IEEE; Registered Professional Engineer; formerly Editor in Chief,* Electronics; *Engineering Group Leader, CBS Electronics.*

Assistant Editors	Ronald K. Jurgen, Edward A. Torrero
Consulting Editor	Donald G. Fink

Fourth Edition

McGRAW-HILL

New York San Francisco Washington, D.C. Auckland Bogotá
Caracas Lisbon London Madrid Mexico City Milan
Montreal New Delhi San Juan Singapore
Sydney Tokyo Toronto

SMPTE proposed Standards are published in the *Journal of the SMPTE*. SMPTE 240M-1988, *Standard for-1125 /60 high-definition producyion.* September 1989. SMPTE274M *Standard* for *1020×1080 Scanning*, October 1994. SMPTE296M *Standard for1280×720 Scanning*, May 1996.

MPEG-2, *ISO/IEC*, Generic Coding of Moving Pictires and Associated Audio" *International Standard 13818-2, Recommendation H.262, (1995E)*. ISO/IEC Copywrite Office, Case Postale 56, CH1211 Geneva 20, Switzerland.

ATSC Digital Television Standard and Guide to the Use of ATSC Digital Television Standard, documents A/53 and A/54 published by ATSC in 1995. ATSC, 1700 K Street NW, Suite 800, Washington, DC.

Audio

J. J. Gibson, *J. Audio Engineerring Society*, September 1986. p. 647–660. Reviews the FCC-BTSC Standard (FCC Bulletin OET60) for and the performance of Television Multichannel Sound (MTS). Includes FCC specifications in FCC Bulletin OET-60.

K. Brandenburg and G. Stoll, "ISO-MPEG-1 Audio: Ageneric Standard for Coding of High Quality Digital Audio", *J. Audio Engineering Society*, 42:10 October 1994.

Digital Television and HDTV

Netravali and B. G. Haskell," *Digital Pictures —Representation and Compression*," Plenum Press N.Y., 1988.

S. N. Baron, "Digital television scalability and interoperability," *J. SMPTE 103:10*, October 1994, p. 673.

S. N. Baron and W. R. Wilson, "MPEG Overview," *J. SMPTE* Vol. 103 No. 6, June 1994.

S. N. Baron, "An overview of the DTTB model," *J.SMPTE* 103–105, May 1994.

Krivocheev, edited by S. N. Baron," The first Twenty Years of HDTV: 1972–1992," *J. SMPTE* Vol. 102, No. 10, October 1993. (Includes many references to international standards committees).

M. Sablatash,"Transmission of all Digital Advanced Television: State of the art and future reflections," *IEEE Transactions on Broadcasting*, Vol. 40, No 2, June 1994.

"Special Issue on Digital Television," *IEEE Spectrum*, April 1996.

D. Anastassiou, guest editor, "Special Issue on HDTV," *IEEE Communications Magazine*, 34:6 June 1996.

"Special issue on digital television," *IEEE Communications Magazine*, 35–5, May 1994.

"Special issue on consumer electronics," *Proc. IEEE*, 82–84, April 1994.

"Special Issues on Digital Television," *Proceedings of the IEE*, 83:6, June 1995 and *Proceedings IEE*, 83:7, July 1995.

24.2 TELEVISION CAMERAS

Laurence J. Thorpe

24.2.1 CCD Technology

The long dominance of pickup tubes in TV cameras is rapidly giving way to charge-coupled device (CCD) technology. Sony Electronics Inc., for example, introduced its last pickup-tube-based camera in 1989. Consequently, the image dissector, photoemissive (iconoscope and image orthicon), and photoconductive (vidicon, Plumbicon, and Saticon) tubes will not be discussed here. Rather, the material presented will concentrate on the deployment of CCD technology in TV cameras. The reader interested in pickup-tube technology is referred to the previous edition of this handbook for detailed information.

The CCD is an analog device like the pickup tube but there the similarity ends. With the pickup tube a given television line is a continuous row; with the CCD a given television line is a row of discrete samples. The signal output from the CCD takes the form

$$F\,[\sin 2\pi(nf_S \pm f_B)]$$

where F_S = sampling frequency and f_B = baseband signal frequency. The baseband signal—the desired useful video output—is accompanied by a series of sideband signals centered about multiples of the basic sampling frequency. These sideband signals are unwanted spurious signals that introduce a form of interference called *aliasing*.

Figure 24.25 shows the baseband signal. Its shape is predictable and has the mathematical form of sin x/x where x is related to the individual picture element (pixel) horizontal width and to the number of pixels (which determine the horizontal spatial sampling frequency). The sampling frequency

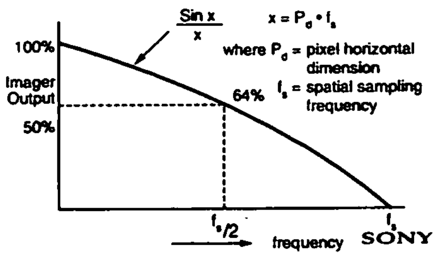

FIGURE 24.25 Baseband signal for a charge-coupled device (CCD).

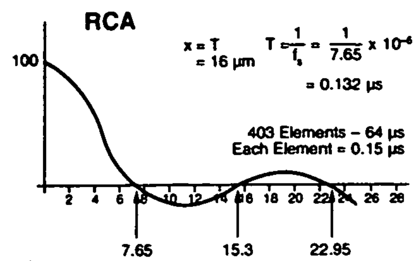

FIGURE 24.26 The early RCA CCD could resolve all frequencies up to 302 TVL/ph as indicated on the sin x/x response curve.

f_S of the sin x/x curve gives a first feel of the bandwidth or limiting resolution capability of the device. The shape of the curve gives a feel for the depth of modulation.

24.2.2 The RCA CCD

The pioneer CCD for the broadcast industry was the RCA CCD. It had 403 pixels, each with a wide horizontal dimension. As a result, the pixels almost abutted one another; i.e., they were almost continuous. The resolution capability of the RCA CCD was

$$403 \times 3/4 = 302 \text{ TVL/ph}$$

where TVL/ph is television lines per picture height. This indicated that the RCA device could resolve frequencies up to 302 TVL/ph. Figure 24.26 shows an examination of this on the sin x/x response curve.

Beyond $f_S/2$ the CCD becomes confused, as predicted by Nyquist sampling theory (in order to unambiguously resolve a given frequency f, one must sample this frequency with at least $2f$ sampling rate).

24.2.3 The Sony CCD

Another early CCD, the Sony ICX-018 imager, with 510 horizontal elements was used by Sony in the BVP-5 broadcast electronic news gathering (ENG) camera. It employed three ICX-018 imagers in a classic RGB optical configuration. If the same contiguous construction as in the RCA CCD were used, then the same formula could be used to show that a 510 element CCD would resolve up to 382 TVL/ph, as shown in Fig. 24.27. If such a CCD was used in a TV camera to a view a television resolution chart containing spatial frequency information up to 4 MHz, the situation would be as shown in Fig. 24.28. All the frequencies in the test chart would be resolved perfectly because they all lie below the critical Nyquist limit of 382 TVL/ph or 4.7 MHz. If this same CCD viewed another test chart containing spatial frequencies up to 6 MHz, aliasing problems would occur as shown in Fig. 24.29. The 5 MHz and 6 MHz bursts shown in Fig. 24.29 are "aliased" with the spatial sampling of pixels. Each frequency produces an interfering frequency which "beats down" into the useful frequency band.

In actuality, the Sony 510 element CCD, unlike the RCA CCD, used narrower individual sensors. There were more gaps between each sensor and the sampling window was narrower. The result was that the sin x/x curve was extended farther out in frequency. If all the statistics of the Sony ICX-018CCD are plugged into the mathematics, the modulation transfer function (MTF) curve is as shown in Fig. 24.30. This would seem to endow the Sony device with far greater resolution prowess than

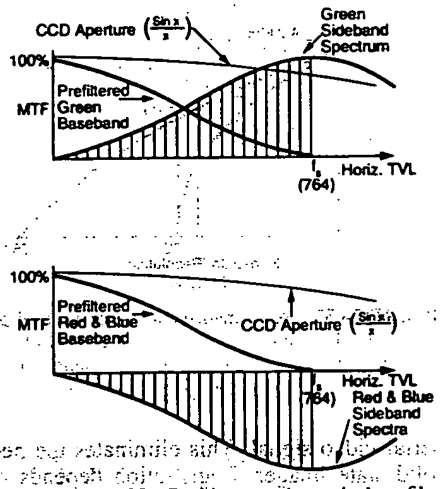

FIGURE 24.35 Pushing out the optical prefilter by a factor of 2:1 to exploit the cancellation effect of the first order sidebands.

$$Y = 0.59G + 0.BR + 0.11B$$

The goodness of the cancellation is also dependent on the precision of the offset.

The final response of the BVP-5 is the summation of the MTF of the lens, MTF of the optical filter, MTF of the CCD imager itself, and the low pass filter electrical characteristics which follow the crucial sample and hold circuit on the output of the CCD.

Figure 24.36 shows the final luminance response of the BVP-5. It compares favorably to a 2/3-in. pickup tube up to about 4 MHz after which it falls off more rapidly. A limiting luminance resolution of 550 TVL/ph is quoted.

24.2.5 Transfer Mechanisms

As stated earlier, the CCD is an analog device and it is a transducer that converts light into electrons. Unlike the homogeneous photoconductive surface of the Saticon or Plumbicon tube, however, the CCD is a geometric array of separate and discrete optoelectrical sensors. Each sensor develops its own electrical charge proportional to the amount of illumination that falls on it. The CCD develops a vast array of separate analog charge "packets" that must be "read out" in the form of a serial video signal.

CCDs are basically shift register structures that simultaneously shift entire arrays of charge packets. Digital control techniques, coupled with a highly efficient method of moving charges from one pixel to another, are used to assemble and transfer the two-dimensional array out of the imaging section of the CCD into a separate CCD register section. The horizontal register organizes a single serial train of analog charge packets. The total process of moving charges out of the sensors is known as the transfer mechanism. There are several well-known transfer mechanism techniques.

24.2.6 Frame Transfer (FT)

Frame transfer was used in the RCA CCD and is used in the Philips designed CCD employed in the BTS LDK-90 CCD camera. FT devices have also been developed in the United States by Texas Instruments and Kodak. Figure 24.37 shows a simplified schematic of the FT structure. Two separate arrays are used: one on which the image is focused (the sensor area proper) and the other which is

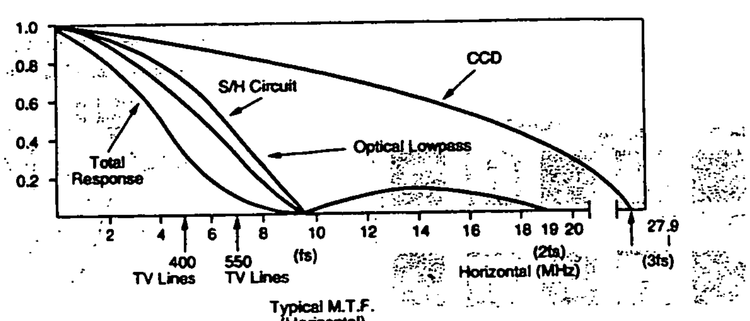

FIGURE 24.36 Final luminance response of the BVP-5 camera.

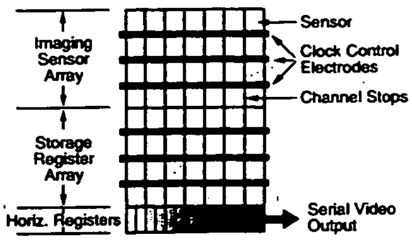

FIGURE 24.37 Simplified schematic of the frame transfer structure.

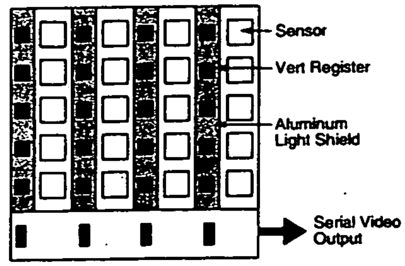

FIGURE 24.38 Simplified schematic of the interline transfer structure.

carefully shielded from light and is a storage section. An individual sensor in the imaging section doubles as a sensor and as a register. The register is used to move or transfer charges.

During the active field period, the FT CCD imaging section develops an electrical charge packet array representative of the optical image focused on it. In the next vertical blanking interval, the sensor becomes a register which clocks at very high speed these charges down into the storage register bank. During the next active field period, the now empty sensors are charged up again with the succeeding image while, simultaneously, the previous image is serially clocked out of the storage bank into the third register bank (the horizontal serial register).

The FT CCD contains sensors that are large and virtually contiguous, and it is a very efficient transfer mechanism, but there is an inherent "contamination" built into the FT CCD. This occurs because the sensors are still being stimulated by the continuously impinging optical image during that brief moment when the charges are "frame transferred" down into the storage register. Since the pixel is a sensor and a transfer register, this causes a low-level vertical smear on the image about 50 dB or 0.2% below normal signal level. The smear would be readily visible in certain scenes, particularly in the 9 dB and 18 dB gain settings. For example, if the scene contains an intense highlight, an unwanted vertical stripe would be centered about the stimulating highlights. With gamma correction, such a stripe would be highly visible. To get rid of this problem, the optical input to the array is obstructed during that brief interval (inside vertical blanking) when the image "drops" down. A mechanical shutter interposed between the lens back elements and the prism block input, synchronized by an electric servo system to the TV vertical drive, accomplishes the desired obstruction.

24.2.7 Interline Transfer (IT) CCD

The IT CCD (Fig. 24.38) differs from the FT CCD by having only one array, which is for imaging, and having the optical sensor separate from the transfer register. During the active field period, the sensors accumulate charges proportional to the illumination striking them. In the next vertical blanking interval, they rapidly empty these charges into the adjacent register bank. During the succeeding active field, while the sensors charge up with the next image, these register clock down vertically the previous "image" into the horizontal output register. The vertical clocking is much slower than that of the FT CCD. The IT CCD must give up optical sensing area to make room for the "interlines" of separate vertical registers. This reduces optical sensitivity, which can be recovered by means to be discussed later. But the use of a separate register does effectively remove the internal vertical smear mechanism of the FT CCD in that the image can be clocked out without worrying about incident light directly contaminating these charges.

No mechanical shutter is needed. A solid-state shutter is available. But with an intense highlight, a vertical smear or vertical stripe problem can occur, although at a far lower level than that of the FT CCD. The smear is also generated by a different mechanism.

The sensor when accumulating the main electron packet from the action of the incident photons also generates a small amount of stray photocarriers. They find an unwanted "sneak path" to the

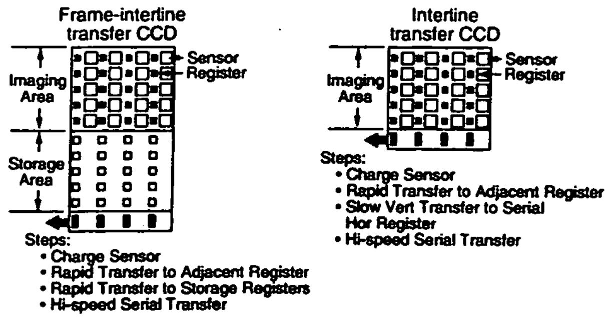

FIGURE 24.39 Comparison of features of a frame interline transfer CCD and an interline transfer CCD.

adjacent registers. This action takes place during the active field period and is clocked down vertically, riding as it were on the top of the previously transferred image.

The IT CCD developed by Sony for the BVP-5 broadcast camera uses semiconductor techniques to reduce this contaminating mechanism to a level 80 dB below normal signal level, which makes it totally invisible under normal imaging circumstances. But when an intense high light stimulates some sensors, even the 80 dB level can become visible.

24.2.8 Frame-Interline Transfer (FIT) CCD

The FIT CCD opens the door for use of a variable speed electronic shutter which introduces a mechanism to achieve clean, blur free, still frame images of subjects in fast motion. Figure 24.39 summarizes the salient features of a FIT CCD relative to an IT CCD.

With the FIT CCD two transfers take place during the vertical blanking interval: the normal interline dumping of the sensor charge into the adjacent register followed immediately by a high speed frame transfer down into the storage area. Because of this action, there is less time for stray photocarriers to accumulate and form a vertical smear. In the Sony BVP-5 camera using the FIT CCD, smear is more than 110 dB below normal signal level.

Figure 24.40 shows how the FIT CCD implements a variable speed electronic shutter system. An electronic shutter involves gathering the image charges built up over a short time period (shorter than normal active field period) and transferring them out as previously described. The other charges generated by the optical image during the remainder of the active field period are discarded. Figure 24.39 shows how a high speed frame transfer in the downward direction assembles the wanted short-exposure charges while a reverse frame transfer, in the upward direction, dispatches the unwanted charges into an overflow drain where they are dumped. Electronic timing control of these two frame shifts can alter the time when the electronic shutter is open and when it is effectively closed.

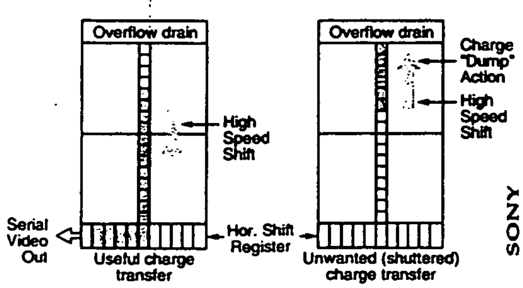

FIGURE 24.40 Illustration of how a frame interline transfer CCD implements a variable speed electronic shutter system.

24.2.9 Pixel Quality

The individual CCD pixel is a complex semiconductor. Different designs have emerged from different manufacturers. Figure 24.41 shows a cross section of an individual pixel in the Sony ICX-018 Interline CCD used in the BVP-5 broadcast camera. The individual pixel design determines the sensitivity, dynamic range, signal-to-noise, highlight handling, lag, and colorimetry performance attributes of the camera.